Initially, more current is needed to increase the temperature of the heater element 1-*f*. As the temperature begins to increase, the current can be decreased until both the current and temperature levels achieve a steady state balance.

Returning to FIG. 15, when the current peaks (step 104), the ECU 3 will store the measured current value (step 106) and the time it took to reach the peak current (step 108). These values are then compared to prestored threshold limits (steps 110–112) to detect a fault (step 124) if the measured current is too high or the heater element 1-*f* takes too long to heat up. Upon the detection of a fault, a malfunction indicator light is turned on step 126), and the cold start apparatus 1 is bypassed in favor of portion injection operation (step 128). This process protects the heater element 1-*f* from overheating or having a dangerous over current condition.

In a similar manner, the steady state current level is compared to a prestored threshold level to detect any fault conditions and avoid operation of the heater element 1-*f* during cold start idle, if the steady state current is out of bounds (steps 114–118). The measured steady state current value is compared to expected values based on several engine operating parameters, including fuel flow rate, ambient air temperature, mass air flow rate and engine vacuum.

Lastly, after the idle period during cold start, the ECU 3 checks that the cold start injector 1-*d* has ceased emitting fuel and that the idle speed control valve 1-*b* has closed. If these operations have proceeded properly, the ECU 3 returns to normal engine operation routines (step 130). Otherwise, a fault is indicated (steps 124–128).

FIGS. 18–23 disclose another embodiment of the present invention that provides for more precise idle air flow control to the cold start apparatus 1. The embodiment in FIG. 18 is similar to the embodiment shown in FIG. 1. However, FIG. 18 further discloses a cold start apparatus 1 having an idle air inlet 1-*a* connected to the air passageway 22 adjacent to but downstream of the location of the throttle 9 when it is in a closed position (indicated by the vertical dotted line depiction of the throttle plate in FIGS. 18 and 19). In this embodiment, the throttle 9 is located within a tapered bore 20 that in part covers the opening of the idle air inlet 1-*a*. The tapered bore 20 is dimensioned to provide a seal about the throttle 9 for about 20% of its rotational travel. In this arrangement, air is blocked from traveling downstream of the throttle 9 until it has opened about 20%.

The area of the tapered bore 20 that covers the opening to the idle air inlet 1-*a* further contains an air flow hole or plurality of air flow holes 21 as shown in the views in FIGS. 20–23. The views in FIGS. 20–23 are a cross-sectional views of the tapered bore 20 looking into the idle air inlet 1-*a*, taken along the line A—A in FIG. 19.

As shown in FIGS. 20–23, the shape of each air flow hole 21 is designed to allow for increased air flow as the throttle 9 is opened. For example, as the throttle 9 rotates open, the exposed area of the air flow hole 21 is increased (from left to right in the diagrams) thereby allowing for increased air flow into idle air inlet 1-*a*. Different design shapes or numbers of air flow holes 21 allows for varying air flow control to the cold start apparatus 1. As can be appreciated, increased air flow controllability provides improved engine idle stability, especially in large bore throttle bodies and/or large displacement engines.

Advantageously, the tapered bore 20 of the present invention provides sufficient control of the air flow to the cold start apparatus 1 such that the need for another air flow control device (such as idle speed control valve 1-*b*) may be eliminated. In addition, by directing a larger amount of idle air to the cold start apparatus 1, cold start emissions can be reduced through improved vaporization even at high fuel flow rates. This can decrease catalytic converter light-off time and reduce emissions without sacrificing low speed idle stability.

Although the present invention has been described in detail with particular reference to preferred embodiments thereof, it should be understood that the invention is capable of other and different embodiments, and its details are capable of modifications in various obvious respects. As is readily apparent to those skilled in the art, variations and modifications can be affected while remaining within the spirit and scope of the invention. Accordingly, the foregoing disclosure, description, and figures are for illustrative purposes only, and do not in any way limit the invention, which is defined only by the claims.

What is claimed:

1. A cold start apparatus for vaporizing fuel before it is supplied to a cylinder of a multi-cylinder internal combustion engine having a fuel supply, and an air intake passageway having a throttle valve comprising a pivotally secured throttle plate disposed therein, said cold start apparatus comprising:

- a housing fluidly coupled on one end to the air intake passageway downstream of the location of the throttle;
- a cold start fuel injector having an outlet and disposed in said housing;
- an idle air conduit fluidly coupled on one end to the air intake passageway, and fluidly coupled on the other end to said housing for delivering air adjacent to the outlet of said cold start fuel injector for intermixing air with fuel ejected from said cold start fuel injector; and
- a heating chamber having a longitudinal lumen and disposed at the outlet of said cold start fuel injector for vaporizing the air-fuel mixture before it is delivered to the engine cylinder, wherein said heating chamber includes of a plurality of separately controlled independent heating element sections to vary the temperature across the heating chamber.

2. A cold start apparatus according to claim 1 further comprising an idle air control valve for controlling the amount of air delivered to said housing.

3. A cold start apparatus according to claim 1 wherein said idle air conduit is fluidly coupled to the air intake passageway upstream of the throttle valve.

4. A cold start apparatus according to claim 1 wherein the throttle plate is disposed in a tapered bore within the air intake passageway.

5. A cold start apparatus according to claim 4 wherein said tapered bore further comprises at least one aperture adjacent to and downstream of the throttle plate when the throttle plate is in a closed position, and said idle air conduit being fluidly coupled through said aperture to said air intake passageway as the throttle plate is rotated open passed said aperture.

6. A cold start apparatus according to claim 1 wherein said heating chamber further comprises a spiral depression within said lumen to effect the air-fuel mixture passing through the heating chamber to flow in a circuitously swirling fashion therethrough.

7. A cold start apparatus according to claim 1 wherein said heating chamber further comprises a heated surface configured in the shape of a corkscrew, and disposed within said lumen to cause fluid passing through said lumen to flow in a circuitously swirling fashion therethrough.

8. A cold start apparatus according to claim 1 wherein said heating chamber further comprises an inner surface made of a heat conductive material.

9. A cold start apparatus according to claim 1 further comprising an electronic control unit for controlling the operation of said cold start apparatus, said electronic control unit being responsive to at least the engine temperature and to the amount of current used by said heating chamber.

10. A cold start apparatus for vaporizing fuel before it is supplied to a cylinder of a multi-cylinder internal combustion engine having a fuel supply, and an air intake passageway having a throttle valve comprising a pivotally secured throttle plate disposed in a tapered bore within the air intake passageway, said cold start apparatus comprising:

- a housing fluidly coupled on one end to the air intake passageway;
- a cold start fuel injector having an outlet and disposed in said housing;
- an idle air conduit fluidly coupled on one end to the air intake passageway, and fluidly coupled on the other end to said housing for delivering air adjacent to the outlet of said cold start fuel injector for intermixing air with fuel ejected from said cold start fuel injector; and
- a heating chamber having a longitudinal lumen and disposed at the outlet of said cold start fuel injector for vaporizing the air-fuel mixture before it is delivered to the engine cylinder,
- wherein said tapered bore in said air intake passageway further comprises a least one aperture adjacent to and downstream of the throttle plate when the throttle plate is in a closed position, and said idle air conduit being fluidly coupled through said aperture to said air intake passageway as the throttle plate it rotated open passed said aperture.

11. A cold start apparatus according to claim 10 wherein said heater chamber further comprises a spiral depression within said lumen to effect the air-fuel mixture passing through said heater chamber to flow in a circuitously swirling fashion therethrough.

12. A cold start apparatus according to claim 10 wherein said heater chamber further comprises a heated surface configured in the shape of a corkscrew, and disposed within said lumen to cause fluid passing through said lumen to flow in a circuitously swirling fashion therethrough.

13. A cold start apparatus according to claim 10 further comprising a n electronic control unit for controlling the operation of said cold start apparatus, said electronic control unit being responsive to at least the engine temperature and to the amount of current used by said heater chamber.

14. A method for reducing automobile exhaust emissions during the cold start of a multi-cylinder internal combustion engine having a fuel supply, a plurality of fuel injectors located adjacent to separate engine cylinders, a cold start fuel injector and heater, having a plurality of separately controlled independent heating element sections, fluidly coupled to the engine cylinders, and an air passageway having a pivotally secured throttle valve disposed therein, said method comprising the steps of:

- initiating power to the heater for a period of time before the engine is started;
- supplying fuel to the engine cylinders through the cold start injector;
- mixing the fuel from the cold start injector with air to produce an air-fuel mixture;
- passing said air-fuel over said heater elements to cause the fuel to be vaporized;

- supplying the vaporized air-fuel mixture to the engine cylinders when the engine is started; and
- switching from fuel supplied by the cold start injector to fuel supplied by the plurality of fuel injectors after the engine reaches a pre-established threshold measured by temperature or time.

15. A method for reducing automobile exhaust emissions according to claim 14 further comprising the step of suspending power to the heater while the engine is being cranked during engine start up.

16. A method for reducing automobile exhaust emissions according to claim 14 further comprising the step of retarding the engine's spark until the engine temperature reaches about 60° C.

17. A method for reducing automobile exhaust emissions according to claim 14 further comprising the step of discontinuing power to the heater after switching from said cold start fuel injector to said plurality of fuel injectors.

18. A method for reducing automobile exhaust emissions according to claim 14, further comprising the step of cleaning deposits off the heater by momentarily spraying fuel on the heater from the cold start fuel injector.

19. A method for reducing automobile exhaust emissions according to claim 18 further comprising the step of simultaneously suspending the fuel supplied from the port fuel injectors by an amount substantially equal to the fuel supplied by the cold start fuel injector.

20. A method for reducing automobile exhaust emissions according to claim 14 wherein said step of switching from fuel supplied by the cold start injector to fuel supplied by each of the port injectors after the engine reaches a temperature of about 60° C.

21. A method for reducing automobile exhaust emissions according to claim 14 further comprising the steps of:

- measuring the amount of current used by the heater after the heater has reached a steady state temperature;
- comparing the measured steady state current level to a preset threshold current level; and
- triggering a malfunction indicator if the measured steady state current level is different from the threshold current level.

22. A method for reducing automobile exhaust emissions according to claim 14 further comprising the step of limiting the amount of air to be mixed with the fuel by controlling the rotational position of the throttle.

23. A method for reducing automobile exhaust emissions according to claim 14 wherein the heater contains a plurality of separate heater elements, said method further comprising the step of varying the power to the separate heater elements to effect different temperatures in the different heater elements.

24. A method for reducing automobile exhaust emissions according to claim 14 wherein the air-fuel mixture is passed over the heater in a circuitously swirling fashion with respect thereto.

25. A method for reducing automobile exhaust emissions during the cold start of a multi-cylinder internal combustion engine having a fuel supply, a plurality of fuel injectors located adjacent to separate engine cylinders, a cold start fuel injector and heater fluidly coupled to the engine cylinders, and an air passageway having a pivotally secured throttle valve disposed therein, said method comprising the steps of:

- initiating power to the heater for a period of time before the engine is started;
- supplying fuel through the cold start injector,

mixing the fuel from the cold start injector with air to produce an air-fuel mixture;

passing said air-fuel mixture over the heater to cause the fuel to be vaporized;

supplying the vaporized air-fuel mixture to the engine cylinders when the engine is started;

switching from fuel supplied by the cold start injector to fuel supplied by the plurality of fuel injectors after the engine reaches a pre-established threshold measured by temperature or time;

discontinuing power to the heater; and

cleaning deposits off the heater by momentarily spraying fuel on the heater from the cold start fuel injector.

26. A method for reducing automobile exhaust emissions according to claim 25 further comprising the step of simultaneously suspending the fuel supplied from the port fuel injectors by an amount substantially equal to the fuel supplied by the cold start fuel injector during the step of cleaning deposits of the heater.

27. A method for reducing automobile exhaust emissions according to claim 25 further comprising the step of retarding the engine's spark until the engine temperature reaches about 60° C.

28. A method for reducing automobile exhaust emissions according to claim 25 further comprising the step of suspending power to the heater while the engine is being cranked during engine start up.

29. A method for reducing automobile exhaust emissions according to claim 25 wherein said step of switching from fuel supplied by the cold start injector to fuel supplied by each of the port injectors after the engine reaches a temperature of about 60° C.

30. A method for reducing automobile exhaust emissions according to claim 25 further comprising the step of limiting the amount of air to be mixed with the fuel by controlling the rotational position of the throttle.

31. A method for reducing automobile exhaust emissions during the cold start of a multi-cylinder internal combustion engine having a fuel supply, a plurality of fuel injectors located adjacent to separate engine cylinders, a cold start fuel injector and heater fluidly coupled to the engine cylinders, and an air passageway having a pivotally secured throttle valve disposed therein, said method comprising the steps of:

initiating power to the heater for a period of time before the engine is started;

supplying fuel through the cold start injector;

mixing the fuel from the cold start injector with air to produce an air-fuel mixture;

passing said air-fuel mixture over the heater to cause the fuel to be vaporized;

supplying the vaporized air-fuel mixture to the engine cylinders when the engine is started;

switching from fuel supplied by the cold start injector to fuel supplied by the plurality of fuel injectors after the engine reaches a pre-established threshold measured by temperature or time;

measuring the maximum amount of current used to initially power the heater;

comparing the measured maximum current to a preset threshold current level; and

triggering a malfunction indicator if the measured maximum current is different from the threshold current level.

32. A method for reducing automobile exhaust emissions according to claim 31 further comprising the steps of:

measuring the amount of current used by the heater after the heater has reached a steady state temperature;

comparing the measured maximum current to a preset threshold current level; and

triggering a malfunction indicator if the measured steady state current level is different from the threshold current level.

33. A method for reducing automobile exhaust emissions according to claim 31 further comprising the step of suspending power to the heater while the engine is being cranked during engine start up.

34. A method for reducing automobile exhaust emissions according to claim 31 wherein said step of switching from fuel supplied by the cold start injector to fuel supplied by each of the port injectors after the engine reaches a temperature of about 60° C.

35. A method for reducing automobile exhaust emissions according to claim 31 further comprising the step of limiting the amount of air to be mixed with the fuel by controlling the rotational position of the throttle.

36. A method for reducing automobile exhaust emissions according to claim 31 further comprising the steps of discontinuing power to the heater and cleaning deposits off the heater by momentarily spraying fuel on the heater from the cold start fuel injector.

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